PHYSICS

Paper 9702/01

Multiple Choice

Question Number	Key	Question Number	Key
1	C	21	B
2	D	22	B
3	C	23	A
4	C	24	B
5	B	25	C
6	C	26	C
7	A	27	D
8	B	28	A
9	B	29	A
10	B	30	C
11	C	31	C
12	A	32	B
13	B	33	D
14	B	34	D
15	C	35	D
16	C	36	A
17	D	37	A
18	D	38	A
19	B	39	C
20	A	40	B

General Comments

Better performing candidates checked their answers as they went through the paper. These candidates also checked for power of ten errors.
Candidates should ensure that if they miss out a question, they do not misplace all their subsequent answers on the mark sheet.

Comments on Specific Questions

Question 7

The second line of the question was ignored by the majority of candidates and they did not recognise this as was a velocity-distance graph.

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Question 8

Many candidates did not understand the difference between speed and velocity, as answer A was a popular response.

Question 11

A common incorrect response was B, which shows an almost infinite acceleration at the start. The correct answer, C, shows an almost constant acceleration when the object is travelling slowly and a reduction in the acceleration as the velocity increases.

Question 25

The three options, A, B and C, were all frequently chosen. Candidates who performed less well often chose B as their answer. The correct key is C, because the lowest frequency occurs when the length of the instrument is just a quarter of a wavelength between a node and an antinode. The next frequency possible is when the instrument length is three-quarters of a wavelength.

Question 34

Candidates found this question challenging. Many candidates did not see that two of the cells are reducing the overall p.d. to $V_1 - V_2 - V_3$.

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> **Paper 9702/22**
>
> **AS Level Structured**
>
> **Questions**

Key Messages

It is important not to prematurely "round up" figures at an intermediate stage during a calculation as this may lead to an incorrect final answer. Candidates should wait until the final answer before rounding to an appropriate number of significant figures. The number of significant figures needed in the final answer can be judged from the number of significant figures in the question data.

Candidates should be encouraged to present all of their working in numerical calculations. It is important that they state any equation used and then show a clear substitution of the question data into this equation. This will often enable credit to be awarded for the working even when a mistake has been made with the final answer.

Many candidates would improve their performance by carefully memorising the definitions and the specific meanings of the terms in the syllabus. They should be able to demonstrate precise recall of these in the examination.

In a "show that" question, candidates are given the final answer and are asked to show that this is so. For this type of question it is essential to show all of the intermediate steps of the calculation leading to the final answer.

Candidates should always consider whether the final answer has a sensible order of magnitude. When this is not so, they should be encouraged to go back and quickly check their working to see if a simple error has been made.

General Comments

A wide range of marks were awarded on this paper. There were a number of very high-scoring scripts produced by candidates who were able to demonstrate a good understanding of the topics across the full range of the syllabus. Conversely, weaker candidates had opportunities to score marks on the more straightforward parts of the questions.

Comments on Specific Questions

Question 1

(a)   This was a straightforward introductory question that was correctly answered by the vast majority of candidates. Candidates needed to refer to a metre rule or a tape measure. It was insufficient to simply refer to "a ruler".

(b)(i)   The majority of the answers were correct. Most candidates realised that the length of the string needed to have units of metres when substituted into the equation. A small minority of candidates did not appreciate that the mass needed to have units of kilograms when substituted.

(ii)   A common error was to treat the uncertainty values given in the question as absolute uncertainties rather than percentage uncertainties. Another common error was to ignore the effect of the square root function on the total uncertainty. The total absolute uncertainty should be given to one significant figure. This should be accompanied by the value of the speed quoted to the same number of decimal places as the absolute uncertainty.

Question 2

(a) The great majority of the candidates were able to correctly define acceleration. A small minority incorrectly defined it as 'the rate of change of velocity per unit time'.

(b)(i) The majority of the answers were correct. The most common errors were either to confuse the horizontal component of the velocity with the actual velocity or to wrongly assume that the ball had a horizontal acceleration.

(ii) The candidates were given the answer and asked to show that it was correct. In this type of question credit is given for explicitly showing each stage of the calculation leading up to the final answer. Many candidates only showed how the vertical component of the velocity could be calculated from the actual velocity. Those candidates should have also shown how the actual velocity is calculated from the horizontal component of the velocity.

(iii) Stronger candidates were able to directly calculate the time taken from a single equation of uniform acceleration. Others calculated the maximum height reached by the ball and then used this value to find the time taken. Weaker candidates sometimes wrongly assumed that the maximum height of the ball was 24 m. Those candidates would improve their performance by remembering not to confuse the vertical motion of the ball with its horizontal motion.

(iv) Some candidates need reminding that a constant acceleration will result in a constant gradient of the velocity-time graph. The stronger candidates appreciated that the graph line would intercept the time axis at the time when the ball was at its maximum height and that the graph line only needed to be drawn to $t = 1.5\,\text{s}$ when the ball hits the wall. The majority of candidates either drew their straight line graph in the wrong position or drew a curved line.

(c)(i) There were a number of different ways to calculate the maximum height of the ball. Most candidates were able to select an appropriate equation of uniform acceleration. The data was sometimes substituted into the selected equation without carefully ensuring that all the signs were correct. It is recommended that candidates practise using equations of uniform acceleration in situations of deceleration where it is essential that all of the data is substituted with the correct signs.

(ii) The vast majority of the candidates found the calculation of the mass to be straightforward. Only a few inappropriately used $g = 10\,\text{m s}^{-2}$ in their calculation.

(d) The most common answer was to incorrectly assume that the increased gravitational force on the increased mass would lead to a greater deceleration so that the maximum height would be decreased. Very few candidates understood that, without air resistance, the deceleration of the ball would be the same so that the maximum height would be unchanged.

Question 3

(a)(i) Candidates are expected to be able to recall the meanings of the terms in the syllabus with precision. The majority only vaguely referred to "force multiplied by distance". A full statement should refer to "force multiplied by distance moved in the direction of the force". It should be noted that a symbol equation on its own is not sufficient as the symbols are not explained.

(ii) A significant number of answers did not make it clear that the energy due to the deformation was stored energy. The weakest candidates sometimes attempted to state what is meant by gravitational potential energy.

(b)(i) This was very well answered by the vast majority of the candidates.

(ii) Although there were many correct answers, a common error was to use the expression Fx rather than $\frac{1}{2}Fx$ for the work done on the spring. This wrongly assumes that the force on the spring remains constant as the trolley is decelerated. The candidates needed to ensure that the units of the compression were converted from cm to m in order to avoid a power-of-ten error in the final answer.

(iii) This part of the question was generally well answered. A minority of the candidates attempted to use an equation of uniform acceleration. This was inappropriate because the deceleration of the block increases rather than remains constant.

(iv)1 Stronger candidates were able to deduce that constant velocity occurs with zero resultant force and so the block is in equilibrium. A common misconception was that the block cannot be in equilibrium because it is moving.

(iv)2 Stronger candidates were able to deduce that deceleration occurs when there is a resultant force and so the block is not in equilibrium. A common misconception was that the block must be in equilibrium because its speed is zero.

(c) A small minority of candidates were able to correctly deduce that the graph would be a curved line with decreasing gradient. Many candidates simply drew a straight line through the origin, possibly because they were inappropriately thinking of the shape of a force-extension graph when a load hangs in equilibrium from the end of a spring.

Question 4

(a) (i) The candidates needed to give a precise description of a transverse wave. As well as referring to the direction of vibration of particles they also needed to heed the instruction to refer to the direction of propagation of energy. It was insufficient to refer to "the direction of the wave".

(ii) There were many good answers. A minority of candidates attempted, incorrectly, to phrase the principle of superposition in terms of amplitude rather than displacement. Others did not refer to displacement at all; the statement that "when two or more waves meet at a point the resultant wave is the sum of the individual waves" was too vague.

(b) (i) The vast majority of answers were correct.

(ii) Despite the prompt in the question, very few answers considered the path difference. The best answers determined the path difference as a number of wavelengths and then linked this to the phase difference at R and so deduced that there was destructive interference. Candidates should say either that the waves at point R have a phase difference of 180° or that the waves are antiphase. It is not sufficient to say that "the waves are out of phase" without quantifying the phase difference.

(c) (i) There were many good answers. Candidates should remember that the intensity and the square of the amplitude are proportional, not equal, to each other. It is expected that the candidates present their final answers as decimal numbers and not as fractions.

(ii) The majority of the answers were correct. Some candidates did not carefully read the question and gave their answer without a unit.

Question 5

(a) (i) The majority of candidates understood that electric current is a flow of charge carriers.

(ii) Electric potential difference may be defined as "the energy transferred from electrical to other forms per unit charge passing between two points". Many candidates attempted to explain potential difference, but did not give a definition. For example, "the energy transferred when unit charge passes between two points" has omitted the idea of a ratio. Candidates should ensure that they refer to unit charge and not one coulomb. It is always essential to use precise wording when giving the definition of a quantity.

(b) (i) Successful answers tended to have clearly presented calculations that explicitly showed each of the interim steps leading to the final answer.

(ii) Although many candidates realised that the $I–V$ characteristic would be a straight line through the origin, only a small minority drew lines with the correct gradient.

(iii) Generally well answered by the stronger candidates. A common error was to confuse the potential difference across one of the wires with the potential difference across one of the lamps.

(iv)1 Generally well answered by the majority of the candidates. The appropriate symbol equation was usually recalled without difficulty. Some candidates were unable to convert the units of the cross-sectional area from mm^2 to m^2.

(iv)2 This part of the question was effective at differentiating between strong and weak candidates. A significant number of the weaker candidates did not attempt this part of the question.

Question 6

(a) Candidates usually knew that a proton would be formed. Many candidates did not know the proton number or the nucleon number of the β^- particle and of the (electron) antineutrino. Some candidates gave an answer where either the proton number or the nucleon number was not conserved in the decay process and this should have prompted them to recheck if they had made an error.

(b) This part of the question required straightforward recall. Some candidates found it difficult to spell the word "antineutrino". The two most common incorrect answers were "neutrino" and "gamma ray".

(c) The majority of the candidates were able to give the correct answer. Weaker candidates either tended to think that the class was "electrons" or else gave a blank response.

(d)(i) The vast majority of answers were correct.

(ii) The change to the quark structure was known by the majority of the candidates. A significant number of the weaker candidates either wrongly stated that an up quark changes to a down quark or else gave a blank response.

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Paper 9702/33
Advanced Practical
Skills 1

Key messages

Repeated readings

In many experiments it is easy to repeat a test. In Question **2** the range of the projectile can be quickly tested several times. All of the measured values of range should be recorded to the appropriate precision before calculating a mean value. The variation in these values indicates the uncertainty in the mean value. For example, measured values of 23.6, 25.7 and 24.0 cm give a mean value of 24.43 cm and an uncertainty of ± 1.05 cm. If only the mean value is recorded, examiners cannot judge the precision of the original measurements, or even be sure that the test was repeated.

Units

Every measured quantity has a unit, and candidates should include it if it is not already given on the answer line. A quantity calculated from measurements usually has a unit, and this should also be included if it is not given on the answer line. Care must be taken to ensure that values used in a calculation have compatible units. For instance, if a calculation uses a value for g of 9.81 ms^{-2}, then any lengths used should be converted to m.

General comments

The candidates' work was good in most cases, and many scripts were excellent.

Centres reported no difficulties providing the equipment required for use by the candidates.

Skills in making measurements and presenting data were evident for most candidates, and many also demonstrated good evaluation ability.

Comments on specific questions

Question 1

In this question, candidates were asked to investigate the time period of a pendulum rolling across a sloping board. Candidates from many centres had been prepared well in the techniques needed for this question.

Successful collection of data

(b)(i) Almost all candidates recorded a value in the expected range for the angle of slope θ of the board. A few omitted a unit, and in some cases the degree symbol ° was not shown clearly.

(b)(iii) Although most candidates recorded the period T in the expected range, a small number recorded large values such as 5.61 s (suggesting that they had timed a number n of oscillations and recorded nT on the answer line).

In many cases there was no evidence of repeated measurements (see key messages). In this type of experiment nT should be measured several times and averaged before dividing by n.

Range and distribution of data

(c) Having started with the board sloping at about 45° candidates were expected to include measurements both above and below this angle, and most candidates did so.

Quality of data

(d)(i) Most candidates were credited for the quality of their results. This was judged by the scatter about a straight line of the points on their graph.

Presentation of data and observations

Table

(c) Most tables were clear and contained all the required columns of data.

Column headings were always included. Headings always gave the quantity, and usually the correct unit, though weaker candidates put units in the body of the table.

The majority of candidates recorded all their measured values of time (either T or nT) to the same precision. In a few cases this precision was 0.001 s, indicating that they were mean values rather than measured values, so that the consistency of the original data could not be judged.

Values for $1/T^3$ were nearly always calculated correctly, with just a few candidates making rounding errors.

Many candidates had difficulty deciding how many significant figures to give for their $1/T^3$ values. The number of significant figures should relate to the original measurement, so that a measurement of $5T$ of 9.82 s (3 significant figures) should lead to a value of $1/T^3$ of 0.132 s (3 significant figures) or 0.1324 s (4 significant figures).

Graph

(d)(i) For their graph of θ against $1/T^3$, most candidates used simple scales, but in many cases the choice of 1 small square for 1 degree led to the points occupying less than half the grid in the θ direction. If this scale was doubled the increased spread of points would lead to more precise values for gradient and intercept.

Most candidates gained credit for plotting their tabulated readings correctly. Candidates from a few centres plotted their points as large dots, making it difficult to judge the point's coordinates.

(d)(ii) Best fit lines were generally chosen well and drawn clearly, without any changes of gradient.

Interpretation of graph

(d)(iii) Most candidates had been well prepared in finding the gradient and intercept of their line, though weaker answers used too small a triangle when determining the gradient. There were just a few mistakes with reading an intercept value directly from the axis when the graph had a false origin (instead of substituting coordinate values into $y = mx+c$).

Drawing conclusions

(e) Most candidates recognised that a was equal to the value of the gradient and b was equal to the value of the intercept. A few candidates ignored the instruction to use values from part **(d)(iii)** and instead tried to calculate a and b by first substituting values into the given equation and then solving the simultaneous equations.

Many of those candidates who attempted to include units for a and b had difficulty with the unit for a, giving $°\,s^{-3}$ instead of $°\,s^{3}$.

Question 2

In this question candidates were required to investigate the motion of a sphere launched from a ramp.

Successful collection of data

(b)(i) Most candidates recorded a value for the launch angle ϕ in the expected range. In a few cases the precision claimed (e.g. 17.3°) was unrealistic.

(b)(ii) Nearly every value of the height h_1 was correctly recorded to the precision of the measuring instrument (a metre rule).

(d)(ii) Stronger candidates repeated the test and recorded several values of R to the nearest mm. Other candidates recorded only a single value on the answer line. See key messages for further comments.

Estimating uncertainties

(e) R was measured using a metre rule with a precision of 1 mm, but good candidates recognised that the uncertainty in the measurement was much greater than this due to the parallax problems. Examiners accepted an uncertainty in the range 2 to 10 mm, and credit was given if this was expressed as a percentage of R.

   Several candidates used the alternative approach of looking at the scatter of repeated measurements (in terms of half the range of values) and expressing this as a percentage of R.

Quality

(f) After increasing the launch angle candidates measured the new range, the majority finding the expected trend that increased launch angle led to a reduction in R.

Display of calculation and reasoning

(b)(iv) The calculation of v was carried out well, with only rare rounding errors. Many candidates gave an incorrect unit due to mixing of units in the calculation (see key messages).

(c) Most candidates understood that the significant figures in v depended on the significant figures in their measurements, but some failed to name both h_1 and h_2 as the relevant measured values.

(g)(i) The great majority of candidates were able to calculate k values correctly from the two sets of data, though some gave their answers to only 1 significant figure.

Analysis and conclusions

(g)(ii) The comparison of the two values of k and the evaluation of the suggested relationship was done well by stronger candidates, with a clear criterion against which the comparison was judged. The terminology used was not always accurate – "percentage uncertainty in k" was frequently used when referring to the percentage difference between the two k values that had been calculated. Many candidates omitted a stated test criterion, just saying that "the k values were close".

Evaluation

(h)(i) & (ii) The strongest candidates thought carefully about this section and were awarded the majority of available credit.

   The majority of candidates recognised that two sets of data were insufficient to draw a valid conclusion, and went on to suggest taking more readings and plotting a graph.

   Many were credited with identifying the flexibility or movement of the track as a problem. Some went on to describe a way of improving the rigidity (e.g. use a metal or wooden track). Just saying "use a rigid track" was not enough to gain credit.

The difficulty in measuring the ramp angle was often identified, and in some cases a workable non-contact method was suggested (e.g. taking a photo and measuring ϕ from that).

Many candidates pointed out the difficulty with parallax when measuring the range R, and some of them gave a description of an improvement using pointer(s). A clear written description was difficult to produce, and the best answers included a diagram.

The other commonly described problem was that the sphere skidded or bounced away from its landing point so that it was difficult to determine the range. Various methods of making it either stick or leave a clear impression were suggested, and some suggested the idea of making a video recording with a scale in view.

Several candidates described difficulties encountered with Question **1** which were not credited.

A table giving details of other acceptable limitations and potential improvements can be found in the published mark scheme, together with some answers that did not receive credit.

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Key messages

Candidates are to be reminded of the need to read questions carefully in order to make sure they understand the requirements of the question. Calculations and definitions were generally well done. Candidates are to be encouraged to look at their answers to calculations and to spend a moment thinking about whether their answers are sensible.

Candidates need to learn the key words needed in definitions and the fact that definitions do not include any reference to units.

General comments

The paper differentiated well between candidates and there was a good spread of marks.

Comments on specific questions

Question 1

(a)   This law was well stated but many responses missed the reference to point masses.

(b)   It was common that only partial credit was gained here as the idea that the gravitational force provides the centripetal forces (rather than is equal to) was not indicated by many candidates. Weaker candidates tried to rearrange the expression given rather than start from first principles.

(c) (i)   Many candidates were able to complete these ratio calculations; however, they should be encouraged to leave their final answer as a decimal. Some struggled to rearrange their expression and weaker candidates erroneously cancelled the square root in part 1.

(ii)   Most responses calculated T_A here and quoted this as the answer for T_B, hence gaining no credit. The candidates had not recognised that the two satellites had different orbital times.

Question 2

(a) (i)   This was well answered, but weaker candidates missed out the reference to molecules / atom and hence gained no credit. They incorrectly referred to the sum of the potential and kinetic energy of the system. A few candidates tried to answer in terms of the first law of thermodynamics.

(ii)   Some candidates referred to more than one assumption which showed they did not know which one was correct and, therefore, were not awarded credit.

(b)   This derivation was only well answered by the strongest candidates. The easiest way to answer was using $pV = NkT$, as some who started with $pV = nRT$ then just stated $k = nR/T$, which is not acceptable in a derivation.

(c) (i)   This calculation was well executed, however some candidates used the temperature in Celsius, and were awarded no credit.

(ii)   This part was well answered, but some candidates only went as far as calculating the number of moles.

(iii) Most candidates were not aware of the difference between the kinetic energy of a single molecule here and the total internal energy of the oxygen and quoted the same answer as **(c)(i)**.

Question 3

(a) This definition was not well known by the candidates. One error was not indicating that the energy is divided by the mass, by using the word 'per' (for example), and another was through including units in the definition, namely kilograms and Celsius / kelvin.

(b)(i) & (ii) Candidates were most likely to say the second set of data was for increased accuracy, or to take an average. The answer here and in the calculation showed that they did not realised they were eliminating the heats losses to / gain from the surroundings. A significant number of candidates changed the temperature increase of 6°C into a temperature in kelvin.

(c) Even the strongest candidates found this challenging. They were unable to apply their ideas of AC theory and many tried to find the p.d. using the formula with a value of t = 1 s. Others mixed the peak value of p.d. with the root mean square value of power.

Question 4

(a) Most candidates gained credit.

(b) Some candidates were able to use the correct equation here, or they started from the two equations on the formula page for kinetic energy and velocity of a particle in simple harmonic motion. However, many only used one value of displacement in the velocity formula, effectively using $v = \omega x$, or they used the formula for constant speed. There were some power-of-ten errors due to not converting from cm into m.

Question 5

(a) The first part was well answered, but fewer candidates were able to state the change required for the second part.

(b) Candidates were able to convert the binary number into the number 12, but then did not use the voltage of each bit of 2.5 mV to find the signal voltage.

Question 6

(a) This calculation was well answered, with many candidates gaining most of the available credit. The most common error was to forget to multiply the distance the ultrasound travelled by 2. Weaker candidates introduced the absorption coefficient here or used the speed of light for the speed of the ultrasound.

(b) There were many correct answers to this ratio, however candidates should realise that a value greater than 1 shows that the intensity was increasing after travelling through the fat.

(c) This second ratio proved much more challenging as candidates did not know how to manage three parts to the attenuation of the ultrasound pulse.

(d) This statement was well answered, and many responses were expanded to include an explanation.

Question 7

(a) Many candidates started this question well with the correct definition. However, incorrect responses like "the ability to store charge" were still seen.

(b) Many responses showed this derivation clearly and logically. However, weaker candidates just stated the formula already given on the page.

(c)(i) The first part was well answered, but then in part 2 a common error was to use a p.d. of 12 V across the 600 μF capacitor. In part 3 errors were introduced when candidates used ratios to calculate the p.d.; the p.d. is shared in an inverse ratio to the capacitance. Values that, on

inspection, were incorrect were often given here, for example 12 V, equal to the supply voltage across one of the series capacitors.

(ii) This part proved challenging to even the strongest candidates. Few realised that the charge on the capacitor would change and used $\frac{1}{2}QV$, instead of $\frac{1}{2}CV^2$ to calculate the energy stored and new p.d. across the capacitor.

Question 8

(a) Most candidates were able to give two effects here.

(b)(i) The completion of the circuit diagram was not found to be straightforward. The extra resistor was generally more successfully added but not the two input connections to the amplifier.

(ii) Many candidates used incorrect gain formulae here. Some tried to use the potential divider formula.

(iii) This graph proved challenging. Some candidates scored partial credit, for either a horizontal line at the correct level (8 V), or for a straight line of negative gradient from one axis to the other and of correct gradient through 8 V and 1.8 s. Most answers did not show an understanding of saturation of the amplifier.

Question 9

(a) Candidates tended to equate field with force here. They correctly stated the electric field should be directed upwards, but they said the electric field should be in the opposite direction to the force due to the magnetic field, rather than two forces in equilibrium.

(b) This calculation was well executed. Some candidates were only awarded partial credit as they did not explain their working, in other words where the formula $E = Bv$ comes from.

(c) Most candidates gained full credit for this calculation.

(d)(i) Many candidates were able to use the charge to mass ratio here to find the mass of the particle. Fewer were then able to use the conversion factor to convert this to "u".

(ii) There were a few incorrect responses here, even though the question stated the charge on the particle was 3*e*.

Question 10

(a)(i) Many candidates forgot the 40 turns and gave the change in the magnetic flux. Others just used the minimum value of magnetic flux of 3×10^{-6} Wb.

(ii) Candidates gained through error carried forward here. Some corrected the earlier emission of the number of turns and calculated the correct answer.

(b) Candidate responses showed that they did not understand the relationship between the induced e.m.f. and the gradient of the graph showing the flux changing with time.

Question 11

(a) Stating this is the minimum frequency needed for photoelectric emission is not enough to gain credit as this is a paraphrase of the question; candidates needed to include that photoelectric emission is the emission of electrons (from the surface). A few answers missed out "minimum". Many responses would have been improved by reference to electromagnetic radiation or photons.

(b)(i) The most common graph was drawn as a straight line through the origin.

(ii) Candidates did not relate the gradient to the Planck constant. The most common response was to simply state the equation for the energy of a photon.

(iii) There were some good responses here, but some candidates answered as though the work function was changing for different electrons, depending on whether they were on or below the surface. Candidates need to understand that the work function is a constant for a given metal.

(iv) Many candidates tried to apply the fact that the intensity does not affect the minimum frequency required for photoemission but does affect the number of photons and hence number of electrons emitted.

Question 12

(a) Some responses to part **(i)** were in terms of penetration of X-rays. Fewer responses gave correct answers to how to decrease the hardness in part **(ii)**. The answer needed to fully state the tube or accelerating voltage was decreased, or the voltage between the anode and the cathode was decreased.

(b) Many candidates gained full credit here as they understood the advantages and disadvantages of CT scans over standard X-ray images.

Question 13

(a) Candidates were able to show how to get the decay constant from the half-life.

(b) Again this calculation was well done. However, power-of-ten errors were common when candidates used the molar mass as 7 kg instead of 7 g.

(c) Another well performed calculation. Candidates correctly selected and used the exponential formula for the decrease of activity with time.

PHYSICS

| Paper 9702/52 |
| Planning, Analysis |
| and Evaluation |

Key messages

In planning questions, candidates' responses should include detailed explanations of experimental procedures such as control of variables, measurements to be taken, analysis of data.

Graphical work should be carefully attempted and checked. Candidates should use a sharp pencil when plotting data points and use a clear 30 cm ruler when drawing the line of best fit and the worst acceptable line; care is also needed when reading information from the graph.

Numerical answers require candidates to show all their working particularly when determining uncertainties. Full understanding of significant figures is required.

The practical skills required for this paper should be developed and practised over a period of time with a "hands-on" approach.

General comments

All candidates completed the paper. The majority of the scripts were clearly written.

In **Question 1**, candidates did not always describe the method in the necessary detail. Diagrams could also be improved.

In **Question 2**, graphs were well drawn with points and error bars easily identifiable. Candidates should be advised that to gain maximum credit the presentation of mathematical working requires a clear statement of the equation used and substitution of numbers leading to the correct answer. Furthermore the working has to be logical.

It is clear that the stronger candidates have experienced a practical course where the skills required for this paper are developed and practised over a period of time.

Comments on specific questions

Question 1

Candidates were required to model "bungee jumping" by a laboratory experiment. They had to investigate how the maximum distance, h, fallen by an object varied with the spring constant, k, of an elastic cord. Candidates were also required to test the relationship between h and k and to determine the value of the acceleration of free fall, g.

The initial credit was awarded for correctly identifying the independent and dependent variables and for the mass to be kept constant. Most of the candidates gained this credit. A few candidates carried out a basic Hooke's Law experiment, plotting a graph of force against extension. Others correctly identified the independent and dependent variables but did not realise that the mass must be dropped from a constant height.

Credit was available for the method of data collection. Partial credit was awarded for a clearly <u>labelled</u> diagram. Diagrams should include the necessary pieces of apparatus set up as they would be used in the experiment. In this experiment a labelled ruler needed to be correctly positioned vertically and close to the

elastic cord. Rulers drawn "in the air" needed to be supported. Strong candidates scored additional credit for clearly explaining how the rule(r) was fixed and using a set square to ensure that the rule(r) was vertical.

The other credit in this section was awarded for the method of measuring the variables. Mass of the object was measured using a balance / scales. A few candidates confused mass and weight.

Measurement of the spring constant, k required a subsidiary experiment. Candidates needed to measure the force acting on the object, its weight, and the cord's extension when the cord was <u>stationary</u>. It was insufficient to just state the Hooke's Law equation without identifying force and extension. Additional credit was available for the method to determine extension.

The final credit was for measuring the maximum distance fallen by the object after release. A number of candidates confused the maximum distance fallen with the extension of the cord. The maximum distance, h, had to be clearly shown on the diagram or defined plus a ruler to measure the distance for the credit to be obtained.

The new syllabus specifies the credit available for the analysis of data. The majority of candidates were awarded some credit though a few candidates did not realise that the question stated the expression to be plotted on the y-axis. The determination of the value for g was found from the gradient of the graph. The resulting equation required g to be the subject of that equation in order to gain credit. To be awarded further credit the candidate was required to explain how the graph showed that the relationship was valid. Answers were improved by including the word "straight" and including the phrase "passing through the origin".

Only a few candidates gained more than half the available credit in this section although there were some very good answers. Candidates should be encouraged to write their plans including appropriate detail; too often candidates' answers lacked sufficient practical experience. Vague responses did not score.

The most common correct response was the safety precaution which required a clearly reasoned precaution relevant to the experiment. Other popular mostly correct responses were repeating the experiment for each cord to determine average h; keeping a constant starting position; using a video camera with slow motion playback. A few candidates realised that the cord must not exceed the elastic limit or become over stretched. Other additional detail credit was awarded for the method of keeping the starting point constant or dropping object from same position and for a trial experiment to locate approximate point of h to prevent the object hitting the surface.

It must be emphasised that those candidates who have followed a "hands on" practical course during their studies are much better placed to gain credit for these additional details. It is essential that candidates' answers give detail relevant to the experiment in question rather than general "text book" rules for working in a laboratory.

Question 2

The question required candidates to analyse data given for how the time, t, for the temperature of water and metal block to increase by 20 °C, is related to the mass of the metal block, m_m.

(a)   Candidates were asked to determine an expression for the gradient and y-intercept from the graph of t against m_m. This was generally answered well.

(b)   Nearly all candidates gained the initial credit. The majority of candidates calculated the absolute uncertainty correctly for full credit.

(c) (i)   Again, the majority of candidates gained full credit. The points and error bars were straightforward to plot. The main reason for credit not being awarded was to draw large blobs for the plotted points.

   (ii)   Care needs to be taken in the drawing of the straight lines. Shading or discontinuities in the lines were encountered. Candidates should be encouraged to use a sharp pencil with a clear 30 cm ruler which covers all of the points. Several candidates joined the first plotted point to the last plotted point. This was not the best-fit line. The worst acceptable line was drawn well in general.

(iii) Most candidates clearly demonstrated the points that they used to calculate the gradient. To be awarded credit candidates must take care in reading the co-ordinates from the line of best-fit, use a sensibly sized triangle and use the correct gradient calculation using (change in y) / (change in x). A small number of candidates chose points that did not lie on the line of best-fit.

(iv) This part was also well answered showing good clear working in the calculation of the intercept. A common mistake in calculating the uncertainty in the y-intercept was either using the same co-ordinates as the best-fit line (providing it is not the crossing point), or using the same gradient as the best-fit line.

(d) (i) Candidates were required to determine a value of the specific capacity of the metal, c_m, by using the gradient and a value for the constant, k, using the y-intercept. A number of candidates had levels of algebraic skills that made it challenging for them to make c_m and k the subject of the equation. There was a common substitution error in the value for the change in temperature; $293\,K$ was encountered instead of the correct value of $20\,°C$. Other candidates calculated correctly the value of c_m, but lost credit because they quoted its value to one significant figure. Additional credit for the value of k tested the substitution of values with the correct power of ten. Credit for the unit was often not awarded due to inconsistent units of mass in finding the unit for c_m, or wrong algebra in finding the unit for $k.t$. It is highly desirable that candidates set out their working in a clear and logical manner, substituting numerical values for the known quantities in equations.

(ii) Showing working is essential for this part. It was quite well answered particularly by candidates who used the method of adding percentage uncertainties of the gradient, change in temperature, and power. Those candidates who attempted to calculate the maximum and minimum values for c_m tended to make more mistakes by using incorrect combinations of maximum and minimum values.